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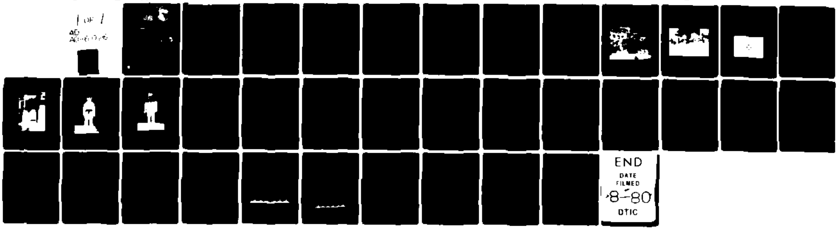

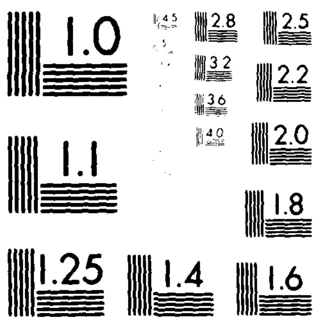

MICROCOPY RESOLUTION TEST CHART

THERMAL AND ACCELERATION EFFECTS ON AIRCREW MEMBERS IN CHEMICAL DEFENSE GEAR

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JANUARY [illegible]

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An experiment was conducted to determine the combined thermal and acceleration effects on aircrew members in chemical defense protective gear in a simulated air-to-ground mission. The subject flew two sorties per day in the Dynamic Environment Simulator. The environmental conditions simulated were typical of a 95th percentile hot summer central European day. Most of the responses seen in the subjects can be attributed to the thermal stress caused by the hot temperatures and the heavy protective clothing.

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PREFACE

The study reported herein was conducted by the Aerospace Medical Research Laboratory, Manned-Systems Effectiveness Division, from November 1978 to January 1979, to determine the effects of chemical defense gear on aircrew performance. It was conducted as part of the scope and feasibility study for the development of a program that will analyze aircrew performance in a chemical warfare environment, Project 6893; Task 08, "Analysis of Aircrew Performance in a Chemical Warfare Environment"; Work Unit 02, "Thermal and Acceleration Effects on Performance in CD Gear."

This study was the result of the combined efforts of an experimental team consisting of members of the Manned-Systems Effectiveness Division and their contractors. Particular thanks go to Mr. Walter C. Summers for statistical design and analysis; Ms. Sharon Ward of Systems Research Laboratories, Inc., for data processing and analysis; Mr. Kaile Bishop of SRL, Inc. for software design and implementation; Mr. Warren Miller and Mr. Willi Buehring for technical advice; Maj. James Yoder, Maj. David Toth, and Dr. George Potor for medical monitoring; Mr. John Frazier and SMSgt. Thomas Shriver for scheduling subjects and managing the centrifuge operating crew; Mr. Clarence Oloff for laboratory assistance; and Mr. Robert Abrams of Raytheon Corp. for managing centrifuge operation and maintenance.

Additional thanks go to Maj. Charles Leone of Aeronautical Systems Division Life Support Systems Project Office for obtaining chemical defense ensembles, to Maj. Dave Bass and Capt. Larry Shingler of the Tactical Air Warfare Center for advice on experimental design, and to the following for their participation – Maj. Michael Rundle, Capt. James Bruchas, Capt. William Canda, Capt. George Valentino, Lt. Richard Holdridge, and Lt. Daniel Seem.

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INTRODUCTION

The Aerospace Medical Research Laboratory (AMRL) has been tasked by Air Force Systems Command (AFSC) to conduct a scope and feasibility study for the development of a program that will analyze aircrew performance in a chemical warfare environment. One of the integral facets of this program is to assess performance degradation caused by wearing gear designed to protect aircrew members from various chemical warfare agents. Aeronautical Systems Division Life Support Systems Project Office (ASD/AEL) developed a protective ensemble, which is currently being issued to tactical commands. The gear is considered to be an interim set pending the development of the next generation of equipment.

This protective ensemble has been flown in tests conducted at the Tactical Air Warfare Center (TAWC), Eglin AFB, Florida. Six pilots flew 36 sorties, 12 of which were double sorties, from the front seat of F-4 aircraft. They were monitored by instructor pilots who occupied the back seat of the aircraft and wore conventional flying gear.

During these tests, extensive physiological data were gathered; however, little performance information was obtained. This pilot study was designed to duplicate the conditions under which the flights at TAWC were conducted. The data gathered in this study are to be used to determine whether flight conditions in a chemical defense ensemble can be simulated.

METHOD

Experimental Configuration

The Dynamic Environment Simulator (DES) was the motion simulator used in this study (figure 1). This centrifuge has three axes of motion and can apply up to 20 G acceleration. The cab was configured with a MACAIR seat (20° seat back angle), a standard restraint system, an isometric sidearm control stick with toggle switches, a weapon arm switch located by the throttle control, a heater capable of maintaining cab temperatures at 27°C, and canvas covers for the cab openings (figure 2).

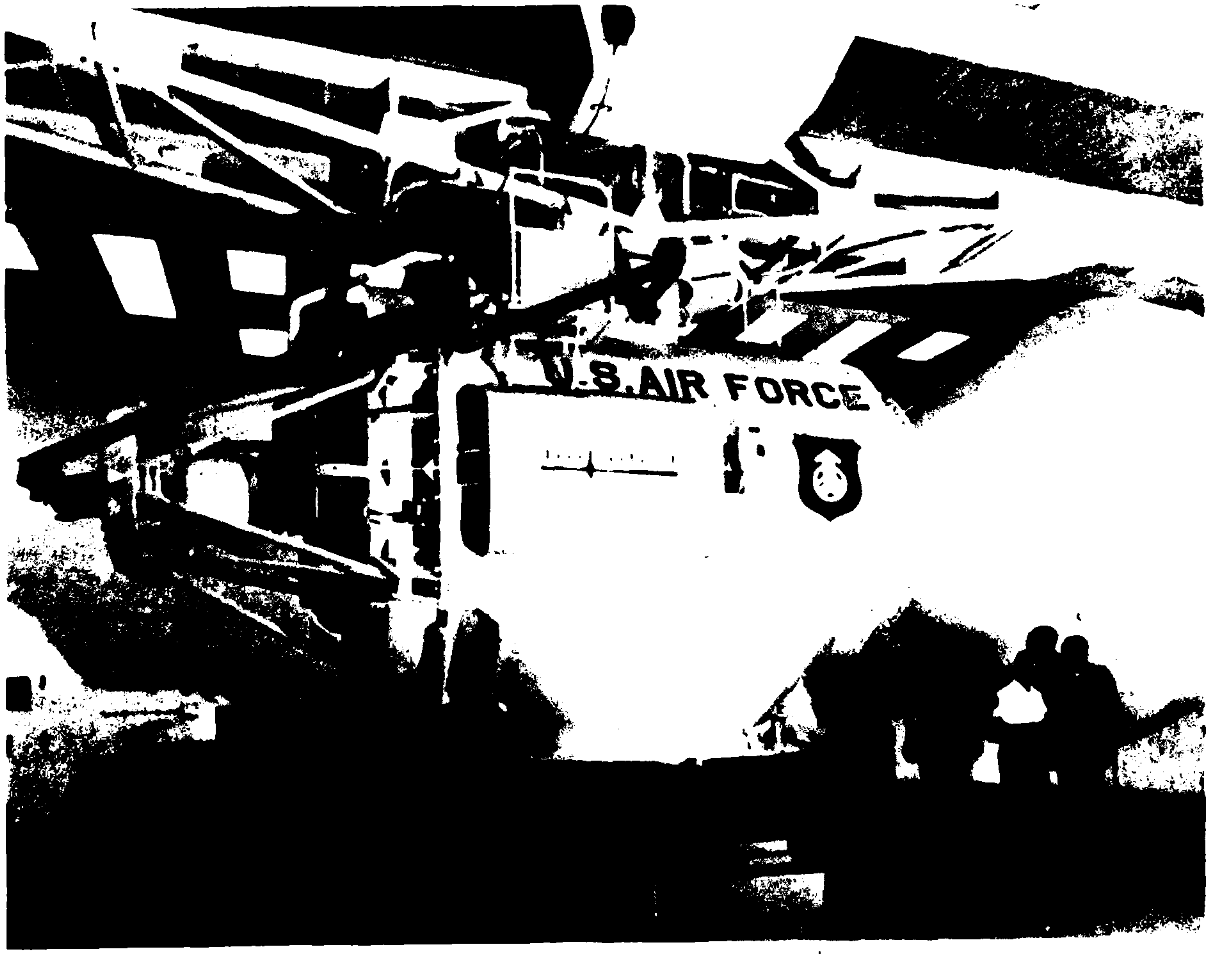

Figure 1 – Dynamic Environment Simulator

Figure 2– DES Cab Configuration

The visual tracking display (figure 3) was a 23 inch television monitor which represented a gun reticle with a pipper and a target. Situated around the reticle in four digital readouts were a 60-second clock, a 5-minute clock, amount of ammunition, and number of hits.

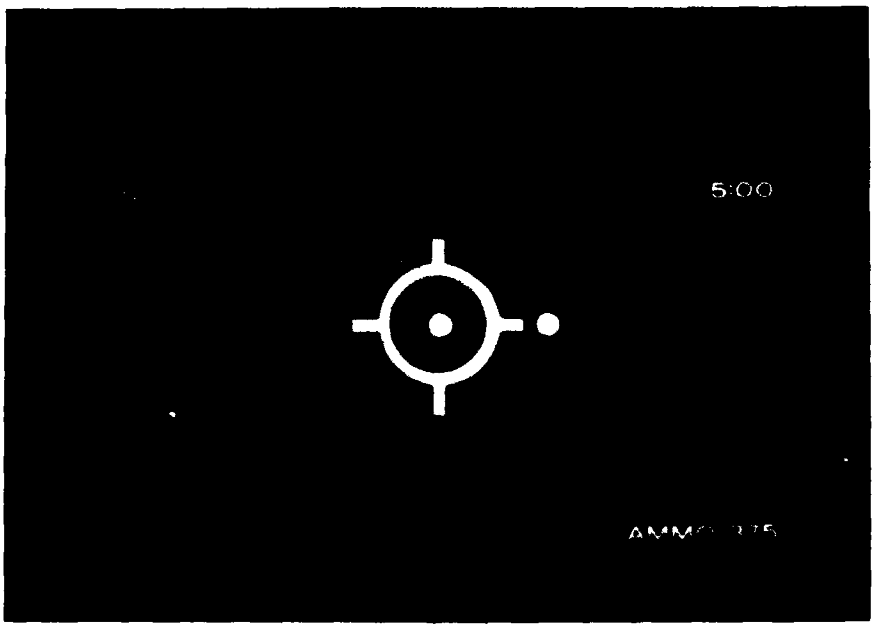

Figure 3 – Visual Display

The subject's lateral stick inputs were used to track an open-loop sum-of-sines task (figure 4). During the lateral tracking task the subject w as given 375 rounds of ammunition which fired at 25 rounds per second in order to obtain a maximum number of hits. The vertical displacement of the control stick was used to track a closed-loop task during which the subject controlled his G_z exposure by tracking the target in the verticle axis (figure 5).

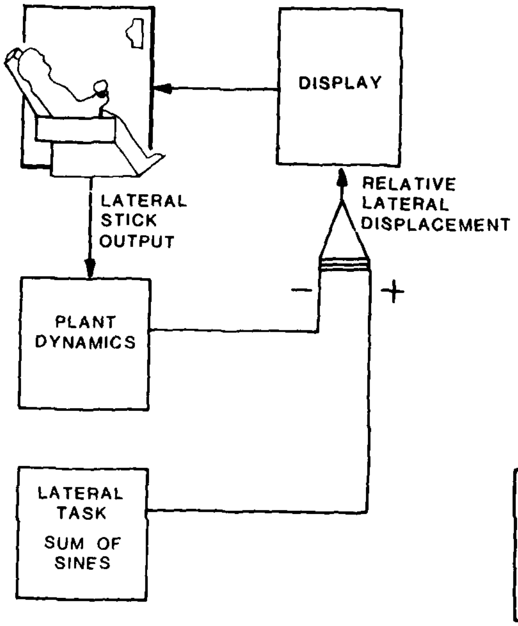

Figure 4 – Lateral Task Block Diagram

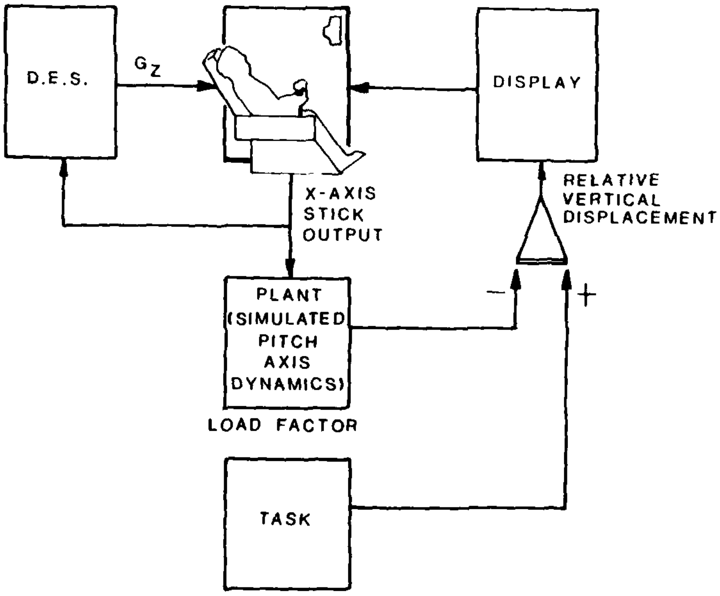

Figure 5 – Vertical Task Block Diagram

Subjects were exposed to thermal stress in the Webber Environmental Chamber. This chamber has the dimensions of 78 inches in height, 44 inches in depth, and 44 inches in width. It is capable of maintaining temperatures over long periods of time in the range from −60° C to 80° C and humidity from near zero to 100%. The maximum rate of temperature change is 1° C per minute and the chamber air temperature can be controlled to 1° C (figure 6).

Figure 6—Webber Chamber

The subjects participated in two configurations. One was in standard flight gear during which the subject wore a flight suit, G suit, nomex flight gloves, boots, flight helmet, and oxygen mask (figure 7). In the second configuration the subject wore the interim chemical defense ensemble consisting of long cotton undershirt and drawers, charcoal impregnated undercoverall, flight suit, G suit, cotton socks, plastic tube socks, boots, cotton gloves, neoprene gloves, nomex flight gloves, helmet (HGU-39/p), CBO mask (MBU-13/p), CBO mask filter (MBU-13/p), and protective hood (HGU-4/p) (figure 8). The subjects were scheduled to alternate configurations and not to run more than twice a week.

Figure 7 – Subject in Standard Flight Suit Configuration

Figure 8 – Subject in Chemical Defense Configuration

EXPERIMENTAL DESIGN

This study was designed to simulate the TAWC flight study environmental conditions, workload, and time. The purpose of duplicating the flight conditions at TAWC was to obtain the same physiological stress in the experimental subjects as was seen in the TAWC pilots. The times and temperatures that occurred in the TAWC study were obtained from TAWC and the School of Aerospace Medicine, which had a representative at the TAWC study. These times and temperatures were then designed into this study to reproduce the maximum physiological stress in the TAWC study.

The following table gives the scenario used, the comparison times, and temperatures from TAWC.

TABLE 1

SCENARIO

	Simulation	*TAWC*
A. Preflight of aircraft		
1. Walk around	10 min. @ 25°C	15 min. @ 27-33°C
2. Closed canopy	20 min. @ 50°C	25 min. @ 45-50°C
B. Low-level flight to target	30 min. @ 27°C	30 min. @ 25-30°C
C. Target area	30 min. @ 27°C	25 min. @ 25-30°C
D. Low-level flight to base	30 min. @ 27°C	30 min. @ 25-30°C
E. Post-mission, closed canopy	30 min. @ 50°C	15 min. @ 45-50°C
F. Alert status	30 min. @ 25°C	45 min. @ 27-33°C
A. Preflight 2nd sorties		
1. Walk around	10 min. @ 25°C	15 min. @ 27-33°C
2. Closed canopy	20 min. @ 50°C	25 min. @ 45-50°C
B. Low-level flight to target	30 min. @ 27°C	30 min. @ 25-30°C
C. Target area	30 min. @ 27°C	25 min. @ 25-30°C
D. Low-level flight to base	30 min. @ 27°C	30 min. @ 25-30°C
Total Time	300 min.	310 min.

The closed canopy time was simulated by the subject sitting in the Webber chamber. Both the preflight walk around time and alert status took place in the large room in which the Webber chamber was located. This room is located adjacent to the DES.

The low-level flight time was simulated in the DES cab at $1G_z$, not in motion (static). During these periods while the DES was static the subject was given a 60 second lateral tracking task followed by a 60-second rest period. In the lateral tracking task a subject obtained as many hits as possible from 375 rounds of ammunition by keeping the pipper on the target. The gun fired at the rate of 25 rounds per second, giving the subject 15 seconds of controlled firing. The target was driven in the lateral axis by the computer and the gun was reloaded at the beginning of each 60 second tracking task. There were a total of 15 static runs before the target area simulation and 15 static runs after the target area simulation.

During the target area simulation the DES was in motion (dynamic). The intent was to simulate an air-to-surface strafing run (figure 9). The DES was brought up to a base line of $1.5G_z$ and the subject was given control of G_z. If he followed the target in the vertical axis he was subjected to a given G profile (figure 10). Each G_z peak lasted 15 seconds. Between the 3 G and 5 G pull ups, 162 to 222 seconds, the subject was given the same lateral tracking task that he had during the static phase. There was no lateral G exposure. During the first 92 seconds of the task the subject was required to do weapon selection with the three toggle switches on the control stick. Proper sequencing and final position were necessary for the subject to be able to fire during the lateral tracking task. Also in order for the gun to fire it was necessary to activate the weapon-arm switch located by the throttle. The subject went through this 5-minute task six times during each target area simulation.

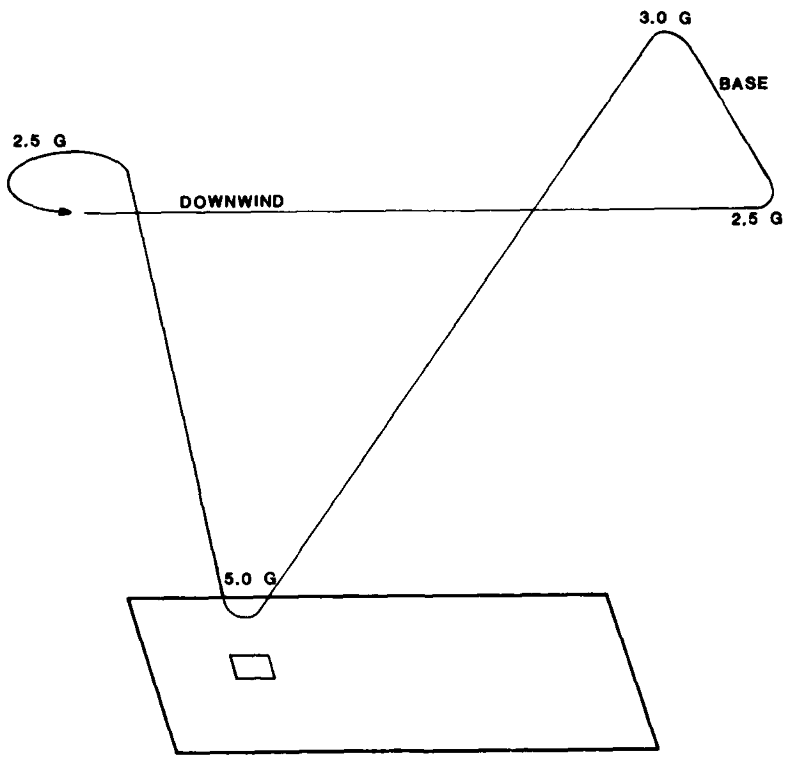

Figure 9 – Simulated Air-to-Surface Mission

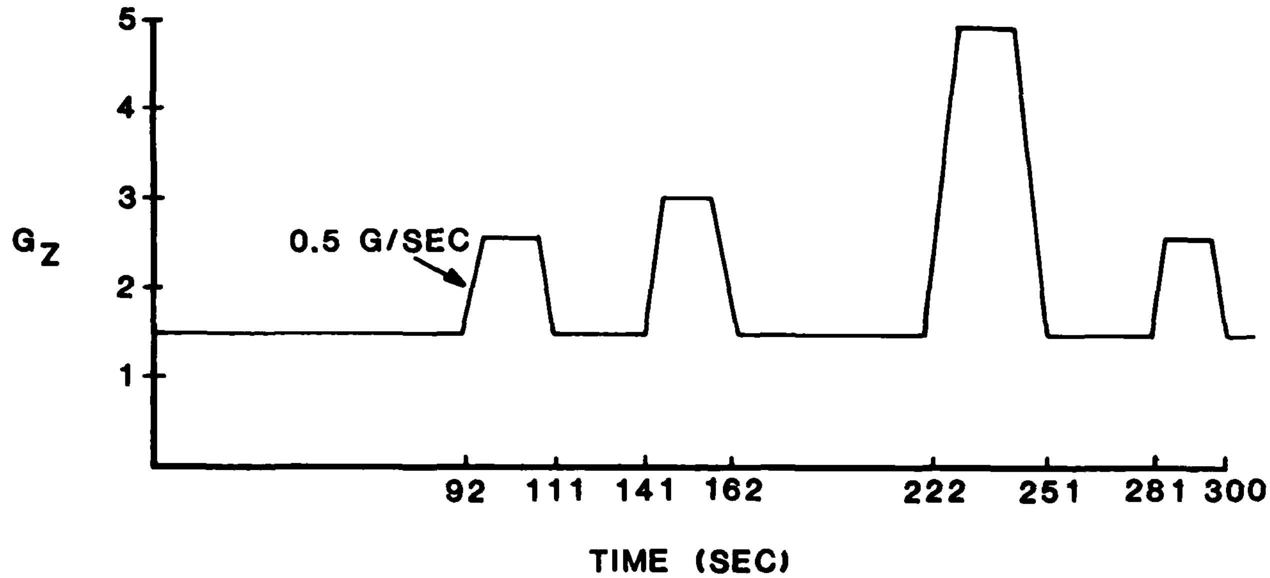

Figure 10 – G_z Profile

The environmental conditions were monitored and recorded at 10-minute intervals. While the subjects were in the Webber chamber, the air temperature, wall temperature, and wet bulb temperatures were controlled. The air temperature was maintained at 50° C ± 1° C. The wet bulb was maintained to give approximately 35% relative humidity. When the subjects were in the DES cab the air temperature was maintained at 27° C ± 3° C. The temperature in the room used for alert status was 25° C.

When the subjects were in the chemical defense ensemble they were not allowed to eat or drink during the alert status between sorties. When they were in standard flight gear they were allowed to eat and drink during the alert status.

Subjects

Six subjects participated in this experiment. These were all members of the acceleration stress panel. All the subjects were military personnel; two had flight status and two had civilian private pilot licenses. None of the subjects were acclimated to heat. Two of the subjects, numbers 1 and 2, had active physical training programs of their own.

In addition to six panel members, a pilot from TAWC, who flew in the chemical defense ensemble flight study, participated in this experiment. The objective data of this pilot are included for comparison with the other subjects. This pilot's subjective observations and recommendations are also included later in this report.

Medical Monitoring

In compliance with Air Force requirements, all centrifuge runs were monitored by a physician. The physician monitored electrocardiogram, instantaneous pulse rate, rectal core temperature, a close-up closed-circuit television picture of the subject's face, and voice communication with the subject. The subject could terminate the run at any time by activating an emergency button. While the subject was in the Webber chamber a physician monitored electrocardiogram, rectal core temperature, and voice communication with the subject. The subject could terminate the heat exposure by verbal request at any time.

DATA COLLECTION AND ANALYSIS

PERFORMANCE

The performance tasks used in this study were adequate to simulate terminal phase of weapon delivery or other two-dimensional aircraft control problems. They did not capture the breadth of difficulty of flying an aircraft. The effect of increasing psychophysiological stress is not usually seen in performance of simple control problems until virtual failure is reached. In a more complete simulation, errors would be expected in maintenance of aircraft and weapons status, decision speed, and error margin of subordinate tasks before primary control task error was pronounced.

Although early enthusiasm for the use of human operator models to predict the effects of stress on tracking performance held much promise, recent studies on control-type tasks during physiological stresses have shown that state-of-the-art application to control tasks has little predictive value. The performance data showed no significant change througout the course of this experiment.

Physiology

There were a number of physiological functions measured during this experiment. A list of the subjects vital statistics is given in Table 2. The responses measured in these subjects were limited to as noninvasive techniques as possible because of the degree of stress placed on the subjects. The fluid status of the subjects was monitored by obtaining nude and clothed weights both before and after each day's run. From these weights the subject's weight loss, percent dehydration, perspiration rate, and evaporative/sweat (E/S) ratios were calculated (Tables 3 & 4). From these calculations it can be said that the subjects had a moderately high degree of perspiration with a moderate degree of dehydration. Measurements of hemoglobin (Hb) and hematocrit (Hct) were taken both pre- and post-run (Tables 5 & 6).

Some estimate of respiratory physiology was obtained by venous blood gases measured pre- and post-run. (Tables 7 & 8). These samples showed some hyperventilation in a few individuals. Most cases showed only an increase in oxygen utilization. In the first several runs 100% oxygen was used because it was thought that this would be the case in a chemical warfare environment. The TAWC study pilots used 100% oxygen only to clear the mask of fogging and therefore 100% was no longer used in this experiment since there was no mask fogging. In several of the subjects a respiratory flowmeter was used to obtain respiratory minute volume (Tables 9 & 10). The measurements of respiratory minute volume, although few, showed no apparent pattern or significant change from normal.

The other measurements taken on these subjects showed a diversity of responses varying among individuals. The serum electrolytes of these subjects all remained within normal limits (Tables 7 & 8). The heart rates and core temperatures also showed considerable variability between subjects (Tables 9 & 10). Core temperature was one of the most varying responses decreasing in some subjects and increasing as much as 1.6°C in one subject with the majority increasing less than 0.5°C.

A measure of the subject's fatigue was obtained by using the SAM-136 Subjective Fatigue Form. These were completed prior to the day's run, during the alert status, and at the end of the day's run (Table 11 & and Figure 11).

TABLE 2
Subjects

Subject Number	*Age*	*Weight Kg*	*Height Inch*	*Surface Area m²*	*Completed Runs in Chemical Defense Gear*	*Completed Run Standard*	*Termination Before 2nd Sortie*
1	32	94.423	75″	2.24	1	1	0
2	28	82.386	72″	2.04	2	1	0
3	24	76.843	72″	1.99	1	1	0
4	36	75.716	69″	1.92	0	0	1*
5	25	62.912	68″	1.75	1	2	1*
6	28	82.040	69″	1.98	0	0	1

**Chemical Defense Gear*

TABLE 3

FLUID STATUS STANDARD FLIGHT GEAR CONFIGURATION

Subject	*Pre-Nude Weight*	*Nude Weight Loss*	*Perspiration Rate*	*Dehydration*	*Dehydration*	*Evaporation/ Sweat Ratio*	*Time in Gear*
	gr	gr	gr/hr	%	%/m2²	%	hr
3	76,843	1032	187	1.34	0.67	64	5.52
5	62,912	763	135	1.21	0.69	72	5.67
2	82,644	1627	261	1.97	0.97	77	6.23
1	94,940	1231	220	1.30	0.58	80	5.60
5	62,856	1632	290	2.60	1.49	86	5.63
Aborted Mission 6	82,040	552	473	0.067	0.0336	39	1.17
TAWC Pilot One sortie only	80,504	712	328	0.088	0.046	58	2.17

TABLE 4

FLUID STATUS CHEMICAL DEFENSE GEAR CONFIGURATION

Subject	*Pre-Nude Weight*	*Nude Weight Loss*	*Perspiration Rate*	*Dehydration*	*Dehydration*	*Evaporation/ Sweat Ratio*	*Time in Gear*
	gr	gr	gr/hr	%	%/m²	%	hr
1	94,423	1300	230	1.42	0.64	70	5.33
2	82,386	2030	354	2.46	1.21	51	5.70
3	76,796	3268	545	4.26	2.14	51	6.00
2	81,616	2448	449	3.00	1.47	44	5.45
5	62,632	1112	203	1.78	1.02	65	5.47
Aborted Mission							
4	75,716	1340	473	1.77	0.92	36	3.28
5	61,800	1068	267	1.73	0.99	45	4.00
TAWC Pilot							
–	80,372	1340	313	1.67	0.88	54	5.28

TABLE 5

STANDARD FLIGHT GEAR CONFIGURATION BLOOD DATA ESTIMATING FLUID STATUS

Subject	*Pre-run*		*Post-run*		*Post-run Urine Specific Gravity*
	Hemoglobin	*Hematocrit*	*Hemoglobin*	*Hematocrit*	
3	17.0	49.5	16.13	49.8	1.030
5	16.3	57.3	15.6	46.1	1.026
2	15.5	46.5	15.3	46.2	1.030
1	16.5	48.0	16.7	48.0	–
5	16.1	49.0	16.1	48.5	1.013
Aborted Mission					
6	15.9	47.0	16.0	47.5	–
TAWC Pilot					
one sortie only	14.7	44.0	15.0	45.5	1.022

TABLE 6

Chemical Defense Gear Configuration Blood Data Estimating Fluid Satus

Subject	*Pre-run*		*Post-run*		*Post-run*
	Hemoglobin	*Hematocrit*	*Hemoglobin*	*Hematocrit*	*Urine Specific Gravity*
1	–	–	18.4	49.0	1.028
2	16.6	47.2	15.4	47.3	1.029
3	16.0	49.0	17.0	51.3	1.029
2	15.1	47.0	15.4	47.0	1.024
5	15.4	47.0	15.3	49.0	1.021
Aborted 2nd Mission					
4	17.6	51.0	19.4	55.5	1.005
5	16.6	49.5	16.9	49.0	1.025
TAWC Pilot					
–	14.9	45.0	15.4	46.5	1.025

TABLE 7

STANDARD FLIGHT GEAR CONFIGURATION VENOUS BLOOD GASES AND SERUM ELECTROLYTES

	VENOUS BLOOD GAS						*SERUM*							
	Pre-run			*Post-run*			*Pre-run*				*Post-run*			
Subject	*PH*	*PCO_2*	*PO_2*	*PH*	*PCO_2*	*PO_2*	*Na^+*	*K^+*	*Cl^-*	*HCO_3^-*	*Na^+*	*K^+*	*Cl^-*	*HCO_3^-*
3*	7.323	56.1	30.5	7.370	57.2	24.6	146	4.8	103	28	145	4.4	101	33
5*	7.327	55.5	23.2	7.312	58.1	29.6	145	4.7	107	29	146	4.7	111	29
2*	7.362	47.6	27.1	7.404	41.0	43.8	141	4.5	104	26	144	4.4	109	25
1	7.353	57.1	40.4	7.369	57.0	29.3	141	4.0	103	31	142	4.2	102	32
5	7.375	69.0	28.3	7.361	67.1	31.4	144	5.2	98	39	145	4.7	105	37
Aborted Mission														
6	7.321	59.7	29.9	7.353	57.4	27.2	143	4.5	100	30	144	4.8	104	31
TAWC Pilot														
one sortie only	–	49.8	29.2	–	51.5	26.7	143	4.4	113	–	141	4.5	113	–

*Subjects breathed 100% oxygen

TABLE 8

CHEMICAL DEFENSE CONFIGURATION VENOUS BLOOD GASES AND SERUM ELECTROLYTES

	VENOUS BLOOD GAS						*SERUM*							
		Pre-run			*Post-run*			*Pre-run*				*Post-run*		
Subject	*PH*	*PCO_2*	*PO_2*	*PH*	*PCO_2*	*PO_2*	*Na^+*	*K^+*	*Cl^-*	*HCO_3^-*	*Na^+*	*K^+*	*Cl^-*	*HCO_3^-*
1*	–	–	–	7.365	47.9	46.4	–	–	–	–	–	–	–	26.5
2*	7.353	47.8	23.9	7.466	43.7	46.0	143	4.5	107	25.8	146	4.4	108	31.0
3*	7.341	54.4	35.4	7.397	42.1	31.9	142	4.3	103	28.0	144	4.5	104	25.0
2	7.362	49.1	48.3	7.443	37.6	73.1	141	4.9	98	26.5	145	4.5	104	25.0
5	7.386	52.8	43.6	–	32.7	103.2	142	4.7	105	30.6	141	4.3	105	24.7
Aborted 2nd Mission														
4*	7.382	55.0	20.0	7.351	53.7	24.1	142	5.1	104	32.0	144	4.7	102	29.0
5*	7.365	52.2	40.5	7.503	28.6	90.9	142	4.4	99	29.0	144	4.4	105	24.5
TAWC Pilot														
–	7.345	54.8	32.2	7.394	49.7	38.3	142	4.4	105	29.0	144	4.4	109	29.5

*Subjects breathed 100% oxygen

TABLE 9

STANDARD FLIGHT GEAR CONFIGURATION
HEART RATE, CORE TEMPERATURE, AND RESPIRATORY FLOW

						Pre-flight 1st Mission			*Post-mission Phase*			*Pre-flight 2nd Mission*		
Subject	*Max Heart Rate*	*Core Temp Rectal (T_r) Start*	*Finish*	*Max T_r*	*ΔT_r*	*Average Respiratory Rate*	*Average Tidal Volume(1)*	*Average Respiratory Minute Volume(1)*	*Average Respiratory Rate*	*Average Tidal Volume(1)*	*Average Respiratory Minute Volume(1)*	*Average Respiratory Rate*	*Average Tidal Volume(1)*	*Average Respiratory Minute Volume(1)*
						Breaths per Minute			*Breaths per Minute*			*Breaths per Minute*		
3	125	37.4°C	37.8°C	38.3°C	0.4°C	–	–	–	–	–	–	–	–	–
5	150	37.8°C	37.6°C	37.9°C	−0.2°C	–	–	–	–	–	–	–	–	–
2	132	36.7°C	37.3°C	37.4°C	0.6°C	–	–	–	–	–	–	–	–	–
1	130	37.3°C	37.3°C	37.5°C	0.0°C	–	–	–	–	–	–	–	–	–
5	158	37.2°C	37.4°C	37.5°C	0.2°C	–	–	–	12	0.772	8.86	11	0.860	8.94
Aborted Mission														
6	120	37.3°C	37.4°C	37.4°C	0.1°C	–	–	–	–	–	–	–	–	–
TAWC Pilot one sortie only	125	37.4°C	37.3°C	37.4°C	−0.1°C	14	0.724	9.87	13	0.706	9.45	–	–	–

TABLE 10
CHEMICAL DEFENSE CONFIGURATION: HEART RATE, CORE TEMPERATURE, AND RESPIRATORY FLOW

						Pre-flight 1st Mission			*Post-mission Phase*			*Pre-flight 2nd Mission*		
Subject	*Max Heart Rate*	*Core Temp Rectal (T_r) Start*	*Finish*	*Max T_r*	*ΔT_r*	*Average Respiratory Rate*	*Average Tidal Volume (1)*	*Average Respiratory Minute Volume (1)*	*Average Respiratory Rate*	*Average Tidal Volume (1)*	*Average Respiratory Minute Volume (1)*	*Average Respiratory Rate*	*Average Tidal Volume (1)*	*Average Respiratory Minute Volume (1)*
						Breaths per Minute			Breaths per Minute			Breaths per Minute		
1	108	37.7°C	37.6°C	38.0°C	−0.1°C	–	–	–	–	–	–	–	–	–
2	112	38.0°C	38.3°C	38.6°C	0.3°C	–	–	–	–	–	–	–	–	–
3	140	37.4°C	37.6°C	38.8°C	0.2°C	–	–	–	–	–	–	–	–	–
2	152	37.3°C	37.7°C	37.9°C	0.4°C	12	0.874	10.05	11	0.809	9.11	11	0.712	7.94
5	191	37.2°C	38.8°C	38.9°C	1.6°C	12	0.803	7.73	14	0.703	10.06	13	0.778	9.64
Aborted 2nd Mission														
4	151	38.2°C	38.5°C	38.8°C	0.3°C	–	–	–	–	–	–	–	–	–
5	170	37.4°C	39.0°C	39.0°C	1.6°C	–	–	–	–	–	–	–	–	–
TAWC Pilot														
–	138	37.4°C	37.7°C	37.8°C	0.3°C	17	0.663	11.16	16	0.667	10.31	16	0.636	10.45

TABLE 11

SAM – 136 *SUBJECTIVE FATIGUE FORM SCORES

I. Chemical Defense Gear

Subject	*Pre Run*	*Alert Status*	*Post Run*
1	15	10	7
2	16	7	9
3	14	9	5
2	12	10	3
5	15	9	4
Aborted 2nd Sortie			
4	14	3	
5	15	5	3
TAWC Pilot			
–	12	9	5
II. Standard Gear			
3	16	13	10
5	14	11	12
2	15	10	9
1	17	9	9
5	16	12	11
Aborted Sortie			
6	12	5	
TAWC Pilot			
–	15	10	1 sortie only

*Form provided by USAF School of Aerospace Medicine, Brooks AFB, Texas

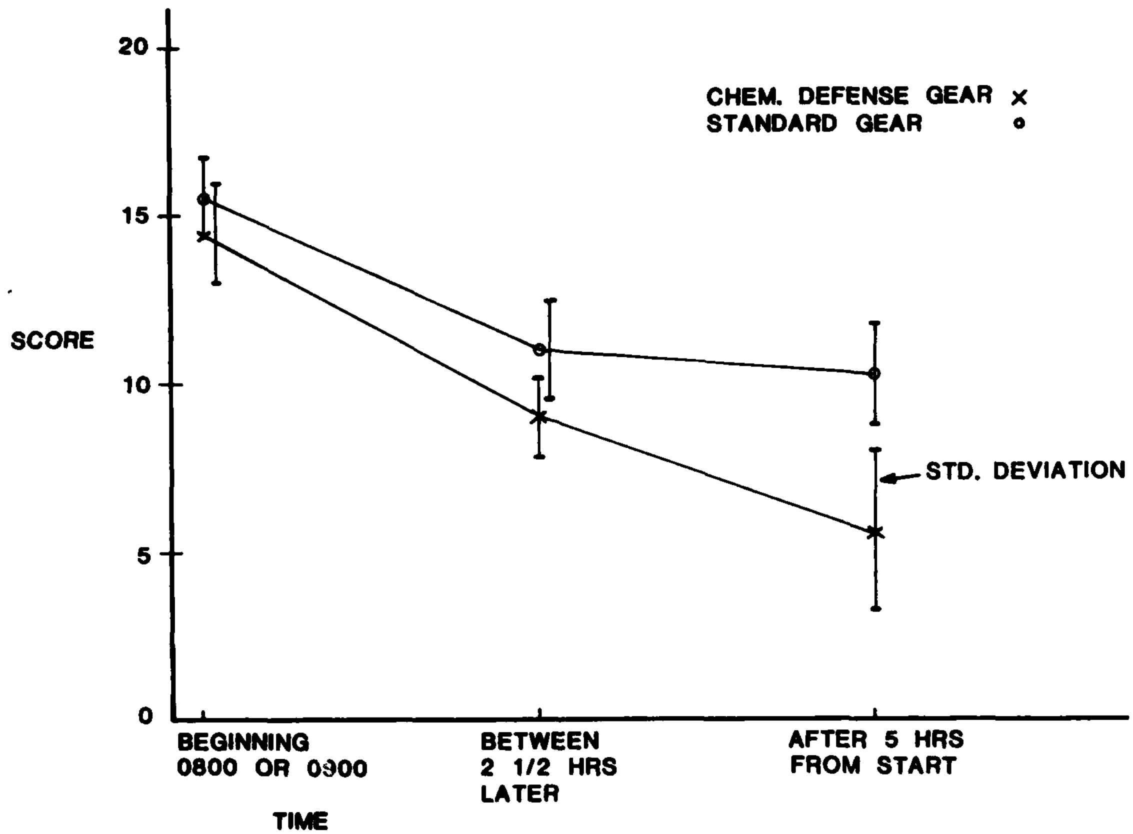

Figure 11. **SA,– 136 Subjective Fatigue Form**
Mean Scores

The main method of comparing this study with the TAWC flight study was by the physiological responses of the subjects as compared with the responses of the pilots. At TAWC there were two individuals who prematurely terminated the test because of heat stress. The main reasons for their difficulty were severe fatigue, mental confusion, and onset of nausea. Three of the subjects in this experiment terminated prematurely because of heat stress; two in chemical defense gear and one in standard flight gear.

The first subject, who was unable to complete a second sortie, was a 69 inch, 76 kg individual who was one of the pilot subjects with over 2000 hrs in F-4 aircraft. This individual first began to have problems during the post mission phase of his first sortie. The subject (no. 4) repeatedly would ask how much time remained of his heat exposure. With about 3 minutes left of his heat exposure, 2 hours and 48 minutes into the run, the subject demanded to be removed from the Webber chamber. The subject was redfaced and complained of a headache. He stated that he would not go back into the Webber chamber as part of the second sortie. Some of the comments made by this subject were that he became extremely bored sitting in the heat chamber, he began to concentrate on his own breathing and heart rate, and he began to feel that he would faint if he did not get out of the Webber chamber. His heart rate changed from 82 beats per minute at the start to 122 beats per minute when he was removed from the Webber; he also had an increase in rectal temperature of 0.2° C. The subject's heart rate remained around 120 for approximately 40 minutes and then returned to normal. This subject lost 1340 grams for a perspiration rate of 475 grams per hour. His subjective fatigue score went from 14 at the start of the day to 3 when he was removed from the Webber. This low score is associated with extreme fatigue.

The second subject who was unable to complete his second sortie was a 68 inch, 63 kg individual with a civilian pilot license. This subject (No. 5) had been through the experiment once before in the standard flight gear without any difficulty. This subject had just begun the static tracking part of his second sortie, 4 hours into the run, when his temperature reached 39° C which was the medical cut-off point. He had complained of being extremely hot and tired during the last 5 minutes of his heat exposure. When moved from the Webber chamber to the DES the subject felt that he would cool off but within a few minutes he felt hot again. The subject's rectal temperature had risen from 37.4° C to 39.0°C for a 1.6° C increase. His heart rate had been 92 beats per minute at the start of the day and at the point when he was removed from the DES cab it was 130 beats per minute. His heart rate remained elevated for approximately 90 minutes and then returned to normal. Some hyperventilation was noted in this subject. He had lost 1068 grams for a perspiration rate of 267 grams per hour. The subject's fatigue scores went from 15 at the start of the day to 5 during the alert status to 3 at the time he was removed from the cab. The subject ran again in the chemical defense ensemble approximately 2 weeks later and completed 2 sorties.

A preliminary assessment of the thermal load imposed by the semi-permeable chemical defense clothing was made using the data from subject No. 5. The overall physiological response and physical conditions are shown during two separate exposures with the subject wearing the standard flight gear compared with that while wearing the chemical defense gear (figures 12 & 13). This subject's aborted run is compared with that of subject 4's aborted run in Figure 14. As both aborted runs were initial exposures with chemical defense gear, the high heart rate may reflect emotional factors such as anxiety. The high heart rate in Figure 14 suggested heart rate might be an important factor and 15 second heart rate counts were made every 30 to 60 seconds during the acceleration portion of the experiment (figure 15). The difference in heart rate response between sortie 1 and sortie 2 are pronounced while the subject was wearing either the standard flight gear or chemical defense gear. In addition, heart rates were higher while the subject was wearing the chemical defense gear as opposed to the standard flight gear.

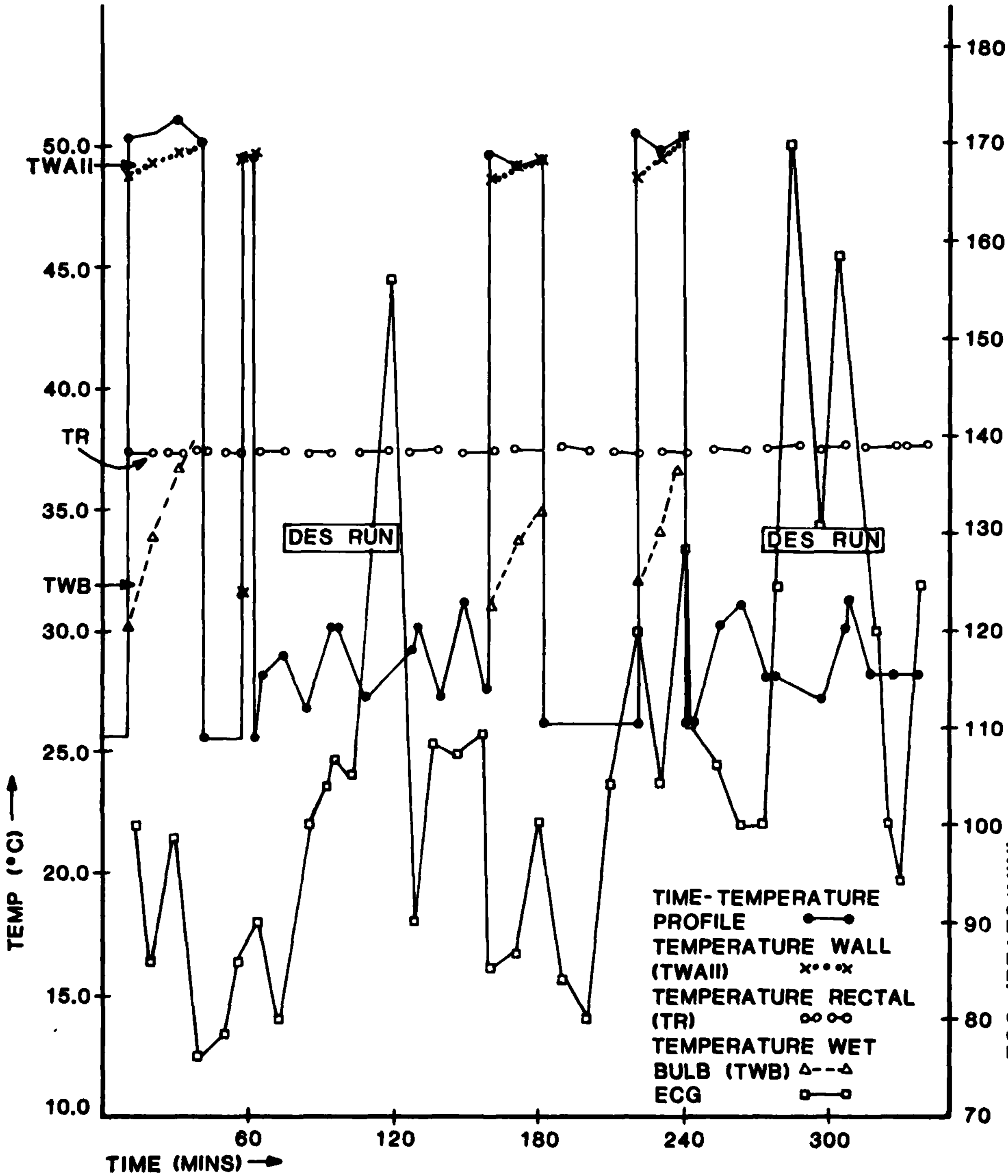

Figure 12–Time – Temperature – Physiological Response of Subject 5 in Standard Flight Gear.

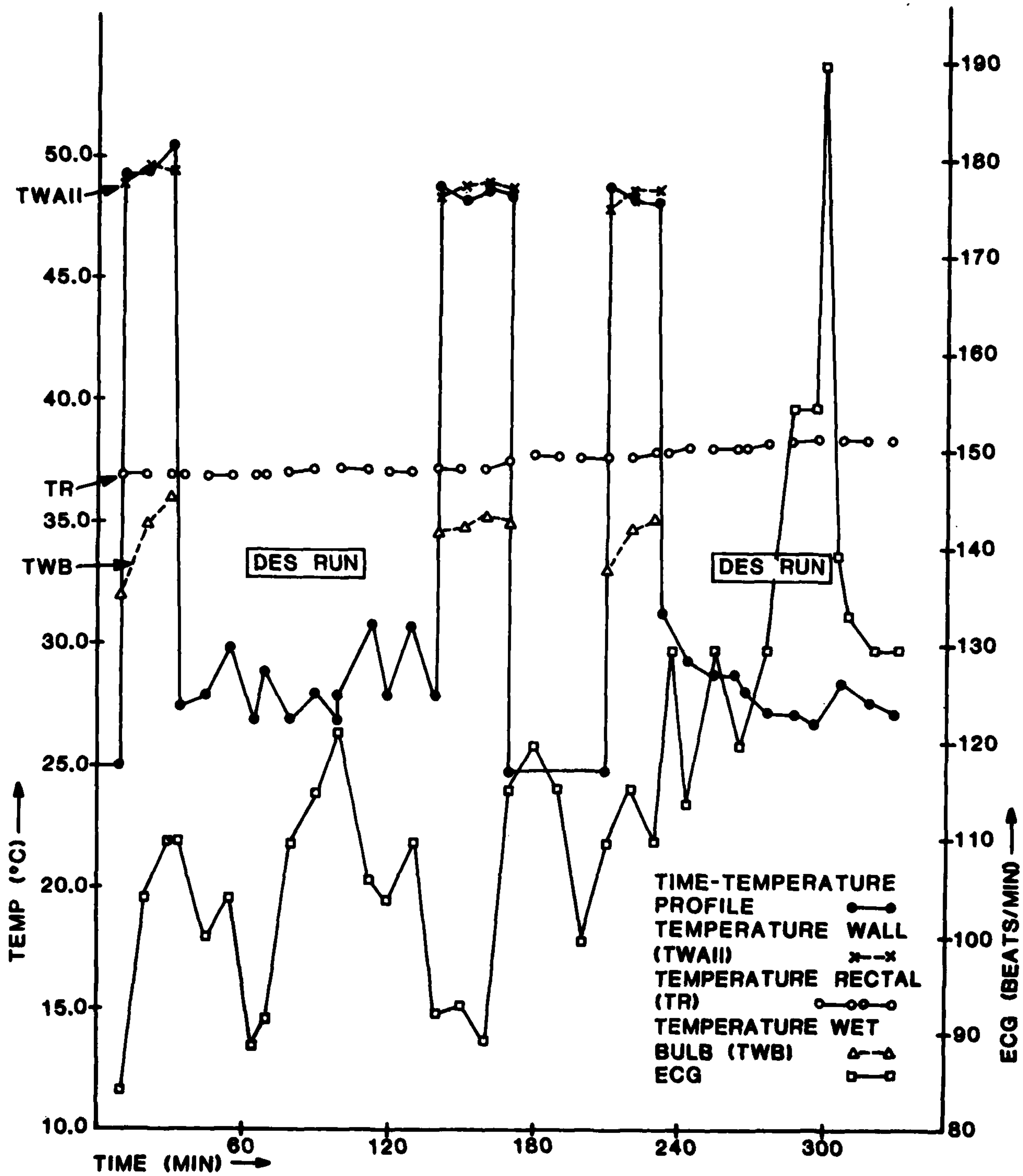

Figure 13 – Time – Temperature – Physiological Response of Subject 5 in Chemical Defense Gear.

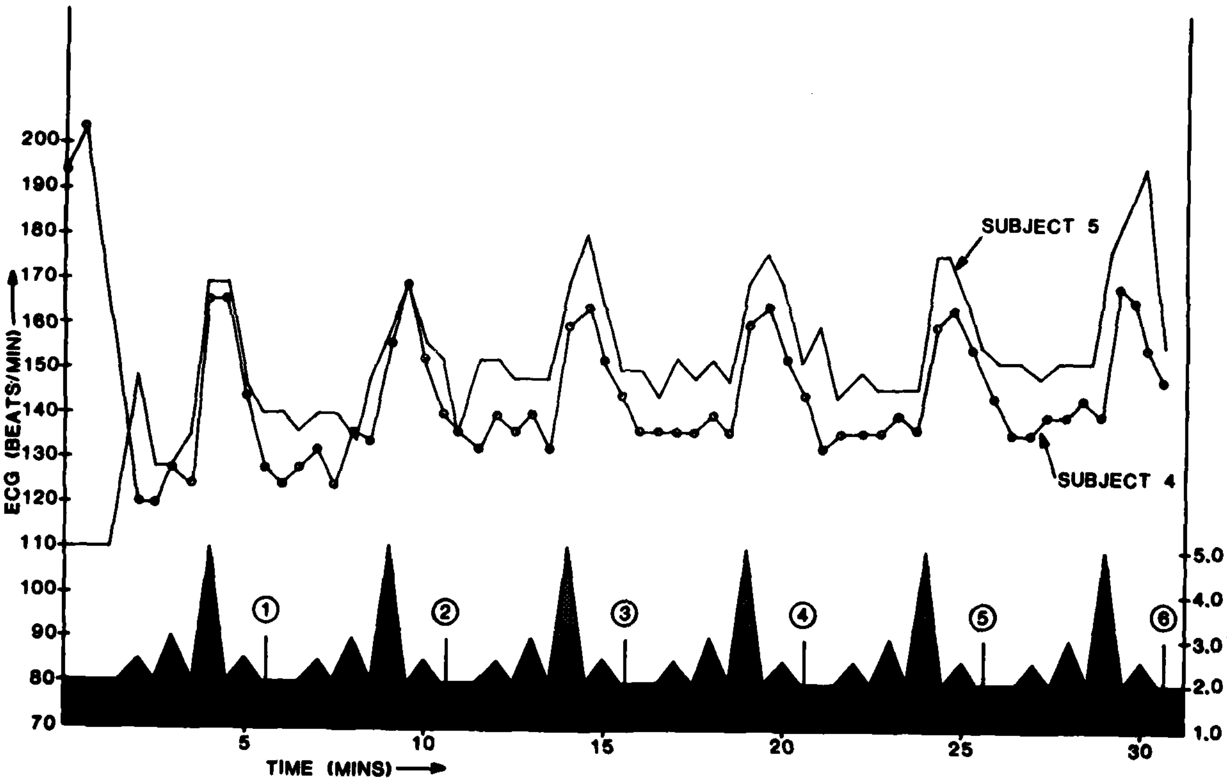

Figure 14 – Comparison of Heart Rates of Subjects 4 and 5 During Aborted Runs in Chemical Defense Gear.

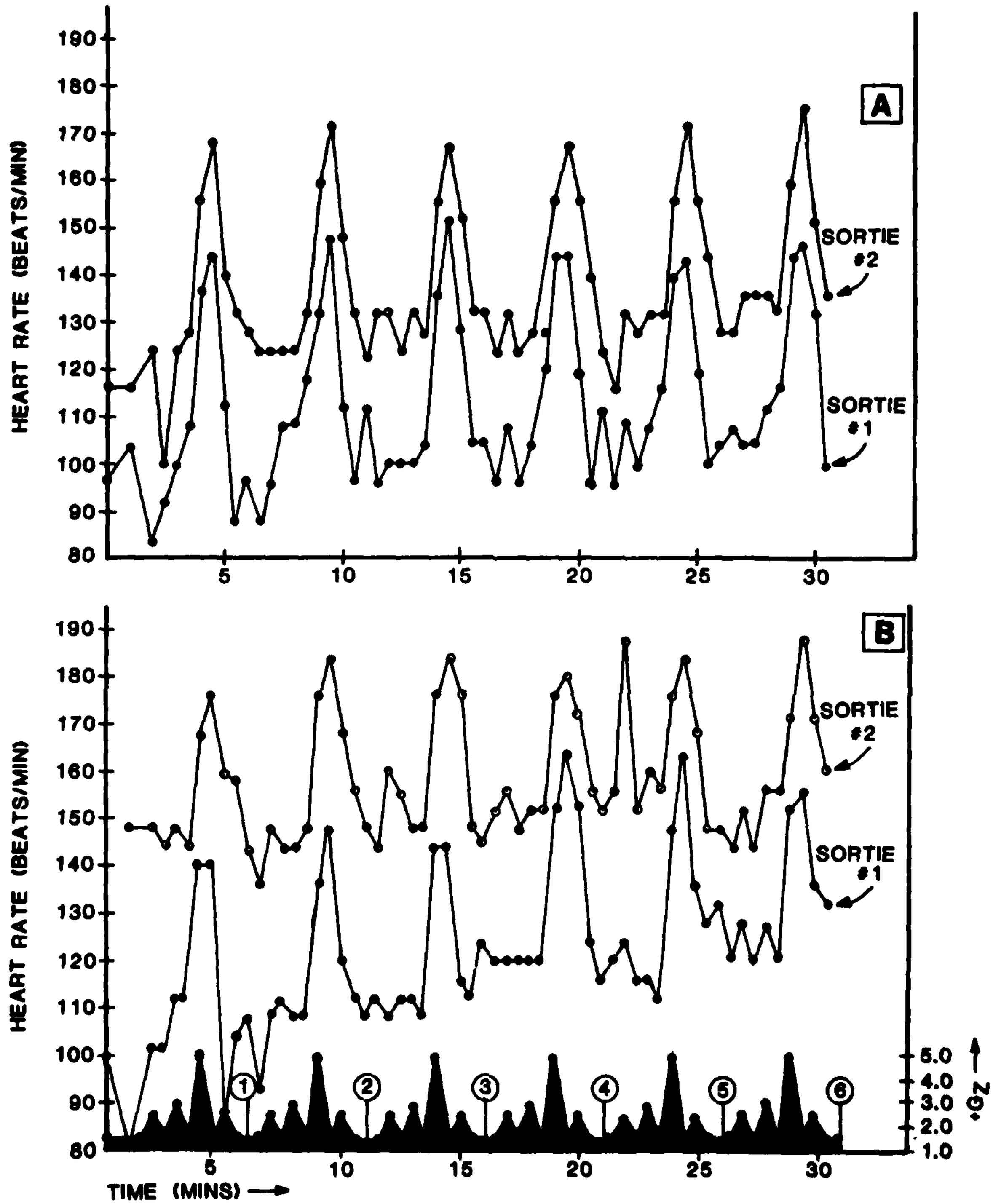

Figure 15 – Comparison of the Heart Rate Responses of Subject 5 While Wearing Standard Gear (A) and Chemical Defense Gear (B).

The third subject that was unable to complete a second sortie was the only subject in the standard flight gear to do so. This individual was a 69 inch, 82 kg individual who stopped his run during the dynamic portion of his first sortie when he experienced nausea. This individual lost 552 grams for a perspiration rate of 473 grams per hour. His rectal temperature increased 0.2° C and his heart rate increased from 82 beats per minute at the start to 108 beats per minute when he stopped the run. This subject did not undergo another experimental run but expressed a desire to do so. His fatigue scores went from 12 at the start to 5 when he was removed from the DES cab.

DISCUSSION

The thermal burden imposed by wearing the semi-permeable chemical defense gear results in elevated core temperatures and heart rates that border on tolerance limits when subjects are exposed to these experimental conditions. While the permeability of the chemical defense gear is higher than expected (because of repeated laundering), the total nude weight loss while wearing either clothing assembly effectively demonstrates the possibility of dehydration after multisorties.

The elevated heart rates during the acceleration portion of the experimental exposure indicate the synergistic effect of thermal loading and the cardiovascular response to accelerative stress. The cardiovascular shift in blood volume to the periphery because of the thermal loading reduces the available cardiovascular reserves to respond to the acceleration stress. Emotional factors such as anxiety further complicate the physiologic responses and hormonal drives may elevate heart rates. These preliminary experiments demonstrate the need for exploratory ameliorative techniques such as head cooling or limited body cooling. Nausea will increase under operational conditions when pilots or other aircrew members are exposed to combined stressors. The performance of a second crewmember, such as ECM or radar officers, should be studied as the incidence of nausea is increased under the combined effects of unanticipated acceleration and heat. The thermal conditions in this study were not unduly severe and the physiological responses would worsen when combined with exercise and high anxiety states associated with operational situations.

Drawing comparisons between what happened at TAWC and what happened during this pilot study was difficult. The subjects in this experiment had problems with helmet fit causing discomfort which was worsened by exposure to heat. Although there was no specific trend seen in physiological responses there was a common factor seen in the heavy perspiration rates and the extreme fatigue. Several of the subjects experienced mental confusion about switch sequence and what amount of time remained in different phases of each experimental run. For instance how many G profiles had been run and how many remained.

The TAWC pilots had problems with helmet fit to the point of having to do modifications to the helmet for the pilots to continue. Another common factor seen in both studies were the heavy perspiration rates and extreme fatigue. The heat susceptible pilots at TAWC experienced some errors in judgement and performance.

The subjective fatigue estimates were obtained using the SAM-136 form both in the TAWC study and in this experiment. In this experiment the mean scores were 14.4 at the beginning of the mission, 9 during the alert status, and 5.6 at the end of the day. Subjective scores of 7 or lower are associated with severe fatigue. Any scores lower than 5 are equivalent to the expression "ready to drop."

The best comparison between the TAWC study and this study were the comparisons made by one of the pilots who flew in the TAWC study and participated in this study. This individual agreed with the time spans but suggested some possible rearrangement between low-level flight time and time at the range. Some changes were suggested in the G profile to make the bomb runs shorter and more of them. He felt that the heat load was great enough but suggested a radiant heat source be incorporated into the DES cab to simulate the radiant load from the sun. Another suggestion was to increase the physical activity in the walk around preflight time in order to increase the internal heat load. The best estimate of how the two studies compared was that this pilot said he felt just as fatigued at the end of the simulated second sortie as at the end of the real second sortie and would rate his performance as minimal in both.

CONCLUSIONS & RECOMMENDATIONS

This experiment was able to simulate an air-to-surface scenario in chemical defense gear. The responses seen in the subjects were similar to those seen in the pilots at the TAWC flight test. Similar difficulties and responses can be expected whenever the chemical defense ensemble is used in hot environments. The responses seen in these subjects are similar to what has been seen in thermal experiments involving heavy protective clothing. This report concludes that the majority of the responses seen in these subjects can probably be attributed to the thermal stress caused by the hot temperatures and heavy protective clothing. We recommend that to verify the conclusions reached, a thermal experiment be designed to test the performance of subjects in the chemical defense ensemble exposed to high temperatures and no acceleration. This experiment should indicate whether further acceleration experiments are needed to evaluate aircrew performance in the chemical defense ensemble.

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